Office of Transportation Technologies

The EE Office of Transportation Technologies supports the energy needs of the transportation sector. Its mission includes: develop and work in partnership with the domestic transportation industry, energy supply industry, and research and development organizations; develop advanced transportation vehicles and alternative fuel vehicles which will reduce oil import requirements, reduce criteria pollutant emissions and greenhouse gases; promote the commercialization, use acceptance, and achievement of the vision of advanced transportation technologies and alternative fuels; and develop a technology base to enable the transportation industry to sustain a strong competitive position in domestic and world markets.

DOE/EE OFFICE OF TRANSPORTATION TECHNOLOGIES
NREL Funding by Fiscal Year

($ in millions--Budget Authority)

	Fiscal Year*				
Office of Transportation Technologies	1995	1996	1997	1998	1999
Operating					
Biomass Fuels (EB2413)	$21.4	$17.1	$17.1	$17.6	$18.1
Regional Biomass Programs (EB2414)	0.3	0.1	0.1	0.1	0.1
Alternative Fuels Utilization (EE50)	17.0	10.3	10.3	10.6	11.0
Heat Engine Development (EE52)	0	0	0.0	0.0	0.0
Electric and Hybrid Propulsion (EE53)	34.3	34.5	34.5	35.5	36.6
Implementation and Development (EE54)	0.2	0.0	0.0	0.0	0.0
Evaluation and Planning (EE5501)	0.0	0.2	0.2	0.2	0.2
Total Transportation Technologies	$73.2	$62.2	$62.2	$64.0	$65.9
Percent of Total Laboratory Funding	29%	34%	34%	34%	34%

*FY 1995 and FY 1996 are actuals; FY 1997 is best estimate; FY 1998 and beyond are generally projected based on 3% inflation.

Biofuels

NREL is leading a national effort to develop biofuels—transportation fuels from renewable resources—with two major projects: ethanol and biodiesel.

NREL's Biofuels Program is leading a national effort to develop biofuels—transportation fuels from renewable resources—that could dramatically improve the environment, economy, and energy security in the United States. Biofuels can be used in their pure forms or blended with petroleum fuels to reduce carbon monoxide emissions, particulate emissions, and

smog. This enables regions across the United States to better meet the requirements of the Clean Air Act Amendments of 1990. Because our nation has the resources and technology to produce biofuels domestically, these products will help reduce U.S. reliance on imported oil, decrease our trade deficit, and contribute to the creation of major new U.S. industries.

The Biofuels Program at NREL includes two major fuels projects: the ethanol project and the biodiesel project. The mission of these projects is to develop and deploy technologies for producing bioethanol and biodiesel from plentiful, renewable, biomass materials, at costs that will be competitive with the cost of petroleum fuels. For ethanol, these biomass materials include waste wood and logging residues, fast-growing woody crops, herbaceous perennial grasses, agricultural residues, municipal solid waste, and industrial waste. For biodiesel, these materials include oilseed crops, such as soybeans and rapeseed, and recycled cooking oils and animal fats.

Ethanol Project

The near-term goal of the ethanol project is to facilitate commercial, demonstration-scale production of biomass ethanol by the end of FY 2000. To achieve this goal, the ethanol project is organized into three major elements: ethanol research, ethanol process development, and facilitating commercial deployment. Via industrial partners, these three elements work in concert and are highly interdependent.

Genetic engineering drives down ethanol cost

Increasing concern about air pollution accelerated ethanol production in the United States from 50 million gallons in 1980 to almost 1.5 billion gallons in 1995. Almost all of this homegrown transportation fuel was made from corn at a cost of about $1.22 per gallon. Recent breakthroughs in genetic engineering may soon lower ethanol costs to 70¢ per gallon, making it more competitive with gasoline.

Lower costs can be achieved by squeezing more ethanol from the same amount of biomass—and that's just what NREL researchers can do with a genetically engineered bacterium known as *Zymomonas mobilis*. The improved strain produces 30% more ethanol by fermenting two kinds of sugars found in plant material: glucose and xylose. Other microorganisms ferment only the glucose found in the cellulose portion of plant material.

In addition to streamlining ethanol production, this breakthrough opens the door for economical conversion of many abundant, renewable feedstocks besides corn. NREL researchers are working with companies such as the Amoco Corporation, Stone and Webster Engineering, and Arkenol to investigate the use of discarded newspapers and agricultural wastes such as rice straw (the plant material left behind after rice harvesting).

This technology garnered a prestigious R&D 100 Award in 1995, ranking it among America's top 100 scientific innovations of the year.

The original bacterium developed in 1995 could not ferment a third sugar in plant material called arabinose, which is a significant component of many agricultural residues and plants being considered as dedicated energy crops. In the latest improvement, NREL has developed a strain of the bacterium that also ferments arabinose, increasing the potential yields and reducing the cost of ethanol from biomass even further.

The primary goal of ethanol research is to develop improved technology for the conversion of biomass to ethanol. Only through improved processes can the production of ethanol from biomass feedstocks containing cellulose and hemicellulose (the woody parts of plants) be cost competitive with gasoline. NREL has targeted three technical steps critical to low-cost ethanol: biomass pretreatment, cellulose breakdown, and biomass sugar fermentation. A team of NREL engineers and scientists, working closely with numerous university subcontractors, has realized significant improvements in these areas in the last 3 years. These include improved pretreatment concepts, new fermentation microorganisms, and genetically modified cellulose-degrading enzymes. With continued support by DOE, these efforts are expected to yield technology improvements key to commercial success of biomass ethanol in the next 5 years or less.

Putting these process steps together—ethanol process development—is a second area of emphasis for the ethanol project. Each research target, including pretreatment, cellulose enzymes, and fermentation, must be proven to function together in an integrated process to efficiently produce ethanol.

NREL's unique process development unit provides the Lab and industry with the ability to refine and improve biotechnology processes for ethanol and other biofuels. (Photo - Warren Gretz, NREL)

Ethanol process development research at NREL has made dramatic progress in the last 2 years in integrating current research developments in a continuous mini-pilot plant. Using waste feedstock, NREL researchers have linked together the currently available technology for pretreatment, cellulase enzymes, and fermentation in one process to produce ethanol while meeting prespecified process efficiencies. This process research is the final yet critical step in proving research advances prior to scaling up technology with industrial partners and is the single largest activity in the ethanol project.

Facilitating commercial deployment occurs through cooperative research and development agreements, research facility-lease agreements, and industry subcontracts. As a typical example, Amoco Energy and their recent partner, Stone and Webster Engineering, operated the NREL process development unit hand-in-hand with NREL in 1996 with numerous highly successful pilot runs. Similar opportunities in 1997 will keep the 8000-square-foot NREL process development unit operating with additional projects and industrial partners to obtain scale-up data for biomass-ethanol processes prior to commercialization.

Biodiesel Project

The mission of NREL's Biodiesel Project is to identify, develop, and deploy cost-competitive, environmentally acceptable, and safe technology for producing biomass-derived diesel transportation

fuels from waste fats and oil feedstocks. Research to this point has documented numerous environmental benefits to using biodiesel in place of petroleum-derived diesel fuel, including significant reductions in particulate matter, carbon monoxide, and hydrocarbon emissions. The nontoxic, biodegradable nature of biodiesel has also been well documented, and there is preliminary evidence that 20% blends of biodiesel and 80% (biodiesel) diesel fuels are much more biodegradable than diesel fuel by itself.

Faced with tougher standards for particulate emissions, urban bus operators may soon be able to use 20% biodiesel blended with diesel fuel to meet these new standards. National parks such as Yosemite and Yellowstone are beginning to look at biodiesel as a way of reducing the growing problem of air pollution associated with tourist travel. Furthermore, biodiesel's ability to provide good lubricity is attracting tremendous attention in the California recreational boat market, where stricter emissions standards in that state have lowered aromatic content and lubricity of diesel fuel, which could reduce engine life. Federal, state and local fleets, which are now encountering requirements for using alternative-fueled vehicles, may be a reasonable niche market for biodiesel in some blend form.

The biodiesel project is working to increase market acceptance and awareness of biodiesel's benefits by working to establish engine performance-based fuel specifications acceptable to fuels providers and engine manufacturers, and also to establish life-cycle-based energy and environmental benefits of biodiesel.

Advanced Vehicle Technologies

DOE established the first Hybrid Electric Vehicle (HEV) Program in response to the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976. Later, the Energy Policy Act of 1992 strengthened this activity, calling on the Department to conduct "a research and development program on electric motor vehicles and associated equipment." In response, DOE increased its emphasis on working with industry on research, development, testing, and evaluation activities to develop the technologies that would lead to the production and introduction of electric and hybrid vehicles.

NREL is committed to supporting Chrysler, Ford, and General Motors in developing a production-feasible hybrid electric vehicle propulsion system.

DOE's Hybrid Propulsion Systems Program is a 5-year, $375-million cost-shared program that supports the efforts and mission of the Partnership for a New Generation of Vehicles Program, sponsored by the White House Office of Science and Technology Policy. The NREL team is committed to supporting the three major U.S. automobile manufacturers (Chrysler, Ford, and General Motors) through subcontracts, in their efforts to develop a production-feasible HEV propulsion system. Complete vehicle systems are now being included as well.

As technical managers for the hybrid automotive subcontracts, NREL uses its core expertise in battery thermal management, component and subsystem optimization, structural engineering, and simulation analysis to solve problems of industry importance. In addition, NREL provides finite- element analysis techniques to solve structural problems and computational fluid dynamics to solve heat- and mass-transfer problems, as well as flow visualization and other measurement-based techniques to quantify performance of hybrid components and their overall systems.

NREL also developed, and now maintains, the HEV Web Site and Office of Transportation Technologies Web Site for DOE. These sites provide a continual means for DOE, industry, and the public to receive information on programs and transportation technologies.

Currently, major propulsion subsystem technologies are being developed under these DOE cost-shared subcontracts with Chrysler, Ford, and General Motors. Complete hybrid propulsion subsystems have been integrated into test mules, which are modified conventional vehicles, and are currently undergoing evaluation. These test mules are scheduled to

Putting it all together for ultra-low emissions

California's new ultra-low emissions vehicle standards for hydrocarbons are really tough to meet. NREL scientists and engineers, working with Benteler Industries, combined knowledge of thermal systems, materials science, and advanced vehicle technology to come up with an award-winning innovation to control emissions.

New engine designs have cut vehicle emissions up to 80% of the emissions during an average commute now occur during the first few minutes of vehicle operation, when the engine is cold. Conventional catalytic converters only function when heated, and an engine turned off for as little as 20 minutes can cool off a converter to a "cold" state.

NREL and Benteler designed a variable-conductance vacuum-insulated catalytic converter that dramatically reduces these "cold-start" emissions by staying hot from one trip to the next, even when trips are 24 hours apart.

Three innovations were combined to create the converter: a compact vacuum insulation seals a vacuum between two layers of metal; phase-change materials for long-term heat storage; and variable-conductance insulation that uses hydrogen gas to release excess heat.

This unique achievement, using ideas originally conceived for buildings and appliance insulation in combination with vehicle engineering, won an R&D 100 award, a Federal Laboratory Consortium Technology Transfer Award, and was a finalist for a Discover Technological Innovation award.

be delivered in FY 1998 and FY 1999. The purpose of these contracts is to validate technologies that yield up to 100% improvement in fuel economy over today's conventional vehicles, or 50 miles per gallon (mpg). The major technologies under development are heat engines (gas turbines, Stirling, and compression-ignition direct injection) and power electronics.

Although NREL's focus is currently on successfully completing the HEV Propulsion Systems Program goals and deliverables, there will be important work to be done beyond this. The team will build on the sound technical foundation developed to meet the 50-mpg targets, and strive to meet or exceed the next higher target of 80 mpg. NREL plans to continue transportation technological developments in accordance with the three main PNGV goals:

- Develop manufacturing techniques to reduce the time and cost of deploying new automotive technologies
- Improve fuel efficiency and emission performance of today's vehicles
- Develop vehicles with triple the fuel efficiency of today's mid-size cars while maintaining or improving safety, performance, emissions, and price

NREL is in a unique position, because of their ability to design, test, and analyze . . . to continue assisting industry . . .

NREL is in a unique position to continue assisting industry with vehicle component testing and evaluation, simulation modeling, and battery thermal management. This unique position stems from the team's ability to design, test, and analyze from a systems-level approach. Critical enabling technologies include energy storage devices; cost-effective, high-efficiency power electronics; compact electric drive systems; and fuel-efficient, low-emission power sources (including gas turbines, Stirling, or direct-injection reciprocating combustion engines).

Some of NREL's key goals for the future include assisting industry with:

- Optimizing integrated propulsion systems to reduce thermal losses and improve component and engine operating efficiencies
- Developing practical high-power energy storage devices such as batteries, flywheels, or ultracapacitors
- Developing low-cost power electronics systems for electric drivetrains and auxiliaries aimed at a five-fold increase in power handling per unit weight
- Further advancing component efficiencies, optimizing propulsion and materials, and integrating the total vehicle system to triple fuel economy by 2004

By FY 2002, the PNGV program intends to prove the feasibility of an 80-mpg vehicle that has the opportunity to be competitive in the marketplace and the ability to reduce pollution and America's dependence on imported oil. NREL plans to be intricately involved with achieving this goal through partnerships and collaborative efforts with U.S. automotive manufacturers, their lower-tier suppliers, and DOE.

Alternative Fuels Utilization

In support of EE's Office of Transportation Technologies, NREL's Alternative Fuels Utilization Program (AFUP) is dedicated to reducing dependence on foreign petroleum usage in the transportation sector while improving air quality through the development and demonstration of engine and fuel technologies that promote the use of alternative fuels.

Program activities include: Advanced Automotive Technologies, Heavy Vehicle Technologies, and Technology Utilization. The Advanced Automotive Technologies group strives to develop innovative technologies enabling the use of alternative fuels in the transportation sector, with an emphasis on light-duty vehicles. Fuels of interest include compressed natural gas, ethanol, methanol, propane, and dimethyl ether.

This light-duty vehicle is being tested on a dynamometer for emissions, fuel economy, and other measures as part of NREL's Alternative Fuels Utilization program. (Photo - Warren Gretz, NREL)

Recent highlights include the development of dedicated ethanol and propane ultra-low emissions vehicles, some using the variable-conductance insulated catalytic converter, which won an R&D 100 Award (see page 1-25). Other promising efforts continue in the area of advanced fuel storage systems.

Major goals ... involve reducing the incremental cost of alternative fuel vehicles and decreasing the vehicle emissions while improving range of operation and fuel economy.

Major goals for the future of the Advanced Automotive Technologies group involve reducing the incremental cost of alternative fuel vehicles and decreasing the vehicle emissions while improving the range of operation and fuel economy. To meet these objectives, the team will evaluate the use of dedicated and flexible fuel vehicle technologies, investigate improvements in engine and vehicle efficiencies, and apply computer technology for the evaluation of advanced automotive technologies.

With over 50 million trucks currently on the road, the Heavy Vehicle Technologies group is focused on an area where major improvements can be achieved. This group of vehicles, while traveling less than a third of the total highway miles, consumes nearly half of all the highway fuel used.

Recently, the Heavy Vehicle Technologies group assisted in creating a roadmap, providing direction and focus, for the development of future technologies in the heavy vehicle area. Another major accomplishment has been the development of an ultra-low emissions ultra-safe school bus.

NREL and its subcontractors are monitoring the performance, reliability, operation and maintenance costs, and emissions of this heavy-duty Peterbilt truck, fueled by liquefied natural gas. (Photo - Acurex Environmental)

The future direction for this group involves continued work on enabling technologies for alternative fuels, both gaseous and liquid, in diesel engines. Emphasis will also be placed on the development of flexible-fueled engines and improvements in engine efficiency while continuing to assess new vehicle technologies.

The primary focus of the Technology Utilization group is to develop the information and technical resources necessary for government, industry, and private citizens to make informed decisions about the use and proliferation of alternative transportation fuels and technologies. The activities are currently divided between Deployment and Information Dissemination. The Deployment area concentrates on the documentation and evaluation of the performance of alternative fuel vehicles introduced into fleets. This work directly supports major legislation, such as the Alternative Motor Fuels Act of 1988, and contributes to reaching the goals of the Energy Policy Act of 1992 and the Clean Cities Program.

A major goal of the Energy Policy Act is the displacement of 10% of the foreign petroleum usage in domestic vehicles by the year 2000 with domestic resources. To reach this goal, the group will increase the number of alternative- fueled and flexible- fueled vehicles within federal fleets and continue the evaluation of these vehicles.

Future efforts ... will move to streamlined testing of vehicles with innovative technologies, observation of the effects of high mileage and reliability on alternative-fueled fleet vehicles, and the satisfaction of future legislative movements.

With more emphasis on local communities, the Clean Cities Program supports an effort to increase the use of alternative-fueled vehicles on a national scale. The program seeks to build the foundations for a sustainable nationwide alternative fuels market. Future efforts in the area of Deployment will move to streamlined testing of vehicles with innovative technologies, observation of the effects of high mileage and reliability on alternative-fueled fleet vehicles, and the satisfaction of future legislative movements.

The Information Dissemination group provides relevant information to the public. The Alternative Fuels Data Center has grown into a national clearinghouse for information on vehicles and programs related to alternative fuels, and can be accessed via the Internet, modem, or hotline (800-423-1DOE).

Many advances have been made in Web development, including advanced multilingual pages, and Web sites for the Clean Cities, Hemispheric Clean Cities, NREL's Center for Transportation Technologies and Systems, and DOE/EE's Office of Transportation Technologies. Future efforts will include making additional full-text technical papers available on the Web, an "intelligent assistant" that will profile users and provide a list of most relevant Web links, and a vastly expanded base of information for public access. Those involved with the AFDC are working to become the leading source of information on not only alternative fuels but also a broad spectrum of transportation technologies.

Initiative: Transportation Technologies and Systems

NREL manages two major programs for DOE, the Alternative Fuels Utilization Program and the Hybrid Electric Vehicle Program. Historically, these programs have been largely subcontracted activities; however, as DOE has reviewed its roles and functions, some shifts in philosophy are occurring. Because of these shifts, NREL is refocusing some of its talents towards greater in-house research activities and capabilities. Proposed research priorities are discussed below.

NREL is developing a new concept to make first-level decisions on what alternative fuel technologies offer the best commercial potential. The objective is to evaluate different alternative fuel technologies on a computer model as opposed to funding multiple hardware testing subcontracts. This will allow evaluation of different automotive technologies without having to build expensive engine and vehicle test cells.

NREL's Alternative Fuels Data Center provides potentially the largest database of alternative fuel vehicle emissions results, critical inputs to atmospheric modeling. (Photo - Warren Gretz, NREL)

NREL is in an excellent position to develop this model, having large amounts of alternative fuels data available that is required as input to the model and additional information provided continuously from subcontractors. In addition, the Laboratory has some previous experience and expertise in this area from the development of a related model.

NREL is also well positioned to develop computer models in atmospheric modeling. Atmospheric modeling helps researchers understand the effects alternative fuels have on air quality. Because of NREL's extensive emissions-testing program, the Laboratory has potentially the largest database of alternative fuel vehicle emissions results, which are critical inputs to atmospheric modeling.

As a result of NREL's technical involvement in the Hybrid Electric Vehicle Program, NREL researchers have developed specific expertise to solve problems for the domestic automotive industry. Examples include research on battery thermal management and development of systems simulation tools to evaluate individual component technology impacts on meeting total vehicle performance objectives. Also, advanced engineering design tools using the capabilities of existing sophisticated software will lead NREL's push for cycle-time reductions by enabling the concurrent engineering design of multiple vehicle systems.

Consistent with planning documents at DOE, NREL is positioning itself to be the lead government organization for technical guidance in evaluating advanced transportation options under the Partnership for a New Generation of Vehicles. The Laboratory will validate analytical tools through rigorous experimental testing of components, which are then integrated into special vehicles to verify performance. Vehicle testing will occur at our auto industry partner's facilities.

NREL's strong knowledge of components, vehicles, and fuels, the extensive databases developed related to these areas, and the Laboratory's relationships with industry, make NREL well positioned to develop novel technologies for the future.